

Mineral resources and conflicts in DRC: a case of ecological fallacy?

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We estimate the impact of geo-located mining concessions on the number of conflict events recorded in the Democratic Republic of the Congo between 1997 and 2007. Instrumenting the variable of interest with historical concessions interacted with changes in international prices of minerals, we unveil an ecological fallacy: whereas concessions have no effect on the number of conflicts at the territory level (lowest administrative unit), they do foster violence at the district level (higher administrative unit). We develop and validate empirically a theoretical model where the incentives of armed groups to exploit and protect mineral resources explain our empirical findings.

JEL classifications: Q34, O13, Q32, N57.

1. Introduction

Over the last three decades a vast literature has developed around the concept of the resource curse. The resource curse broadly refers to the paradox that countries rich in non-renewable natural resources tend to display poor economic performance.¹ Conflict plays a prominent role amongst the several channels proposed to explain this paradox: valuable minerals foster civil wars which negatively affect economic performance (World Bank, 2011). Yet despite the large body of literature addressing the nexus, the evidence remains mixed (Blattman and Miguel, 2010; van der Ploeg, 2011). Collier and Hoeffler (2004) show that countries with larger shares of primary commodity exports are more likely to experience civil wars. However, several shortcomings of Collier and Hoeffler's (2004) study have been

¹Recent contributions to the resource curse literature include van der Ploeg and Poelhekke (2010), Haber and Menaldo (2011), Brückner *et al.* (2012), Wacziarg (2012).

highlighted. First, primary commodities are not homogeneous. As emphasized by specialists of the field, there is an urge to categorize the various types of natural resources into diffuse resources such as agricultural production, and point resources such as mineral resources (Le Billon, 2001; Wick and Bulte, 2006), with the latter being seen as more conflictive (Ross, 2004). On theoretical grounds, point resources—as opposed to diffuse resources—attract violent entrepreneurs that compete for the control of the rents (Mehlum *et al.*, 2002). Recognizing the specificities of mineral resources, a series of papers have sought to identify the specific effect of mineral resources on civil conflicts. The initial evidence based on cross-country analyses pointed at the undisputable role played by mineral resources in both igniting and sustaining civil conflicts (Lujala *et al.*, 2005; Ross, 2006, 2012; Lujala, 2010).

Second, the relationship between mineral resources and conflict is potentially endogenous. For instance, mineral resource dependence may be a direct consequence of actual or expected civil war (Brunnschweiler and Bulte, 2008, 2009). The confounding role of institutions is another source of endogeneity. Fearon and Laitin (2003) and Fearon (2005) emphasize the role of oil revenues in weakening state capacity. More recently, Besley and Persson (2010) formalize this argument by proposing a model of endogenous state capacity formation. They show that natural resource-rich countries will under-invest in state capacity formation, and will therefore be more prone to experiencing civil conflicts.

Third, the cross-country nature of the early contributions to this debate fails to capture the effects of within-country uneven distribution of resources. cross-country analyses also fail to account for unobserved heterogeneity. For instance, Cotet and Tsui (2013) show that oil does not affect civil war in a cross-country estimation, once controlling for country fixed effects. More recent studies adopted a micro-founded approach by exploiting within-country variations. By working with sub-national units of analysis, researchers can draw more accurate causal inference. Buhaug and Rod (2006), Angrist and Kugler (2008), and Dube and Vargas (2013) all identify a positive effect of the presence of natural resources on the occurrence of conflict events. Using geo-referenced data at the 100 square kilometre grid, Buhaug and Rod (2006) find a positive effect of oil and diamond presence on the likelihood of civil conflict. Both Angrist and Kugler (2008) and Dube and Vargas (2013) study the impact of exogenous commodity-price shocks on the level of violence in Colombia. The former show that positive price shocks on cocaine increased violence at the department level, whereas the latter show that at the municipality level the effect of oil and coffee price increases have, respectively, a positive and negative effect on the number of violent events.

Findings from two recent studies by Ziemke (2008) and Sanchez de la Sierra (2013) on the civil conflicts in Angola and the Democratic Republic of the Congo (DRC), respectively, suggest that mineral resources could work as a catalyst for peace, thus casting doubts on the generalization of the relationship between resources and conflict. More specifically, these studies, using geo-referenced data, show that the presence of minerals may contain the level of violence.

This article enriches the micro-founded literature by focussing on the recent conflicts in the DRC. More precisely, we estimate the impact of geo-located granted mining concessions in DRC between January 1997 and December 2007 on the location of conflict events.

The main contribution of this article is to highlight the dramatic consequences of the level of analysis on the relationship between mineral resources and the incidence of conflict. By implementing a two-stage least squares estimation at two geographical levels of analysis, that is, the territory and the district levels, we unveil an ecological fallacy: although there is no evidence that granted concessions affect the number of conflict events at the territory level, they increase the frequency of conflicts at the district level.²

We propose a theoretical mechanism to rationalize these empirical findings, owing much to the literature on crime displacement (Repetto, 1976; Barr and Pease, 1990; Brantingham *et al.*, 2012; Johnson *et al.*, 2012).³ In line with anecdotal evidence, in our model violence affects negatively mining profitability, thus providing strong incentives for mining companies to keep fighting activities far from the production sites (Vlassenroot and Raeymaekers, 2004; Raeymaekers, 2010). This mechanism, which we name the ‘protection effect’, helps explaining the ecological fallacy: valuable minerals do foster conflict, but not in the immediate neighbourhood of the mining sites where violence would disrupt the profitability of the business. Revisiting our econometrics by allowing for a heterogeneous spatial effect of mining concessions on conflict validates the theoretical findings.

This article, therefore, sheds light on seemingly contradictory findings in the literature and highlights the role of the spatial dimension in the empirical literature on conflicts. Our results suggest that valuable minerals do generate violent conflict, but since fighting tends to be located at some distance from the mining sites, the relationship can be identified only by choosing a sufficiently large unit of analysis or by carefully accounting for spatial spillover effects. Failing to do so may result in a non-significant relationship, as in our study, or even generate opposite predictions if the “protection effect” is sufficiently strong at the local level.

2. Background

Since 1996 the DRC has experienced a succession of wars and lower scale conflicts that according to a survey of the International Rescue Committee have been the cause of more than 5 million deaths over the 1998–2008 period (IRC, 2007) and an estimated 1.7 million internally displaced people (Internal Displacement Monitoring Centre, 2011). Whether or not these exact figures are biased

² The ecological fallacy refers to the erroneous assumption that relationships between variables at a more aggregate level imply the same relationships at a less aggregated level. It has also been called a problem of ‘aggregation bias’ or a ‘modifiable area unit problem’ (Wong, 2009).

³ Alternative explanations behind our empirical results are discussed in Section 6.

(Spiegel and Robinson, 2010), their magnitude is indicative of the lethality of these conflicts and of the disruptive effect they had on local living conditions (Pellillo, 2012). The causes of the Congo wars are multiple, complex, and intermingled: the weakness and inefficiency of Mobutu's regime, ethnic polarization, spillover effects from the Rwandan genocide, regional control by foreign powers, and natural wealth have all been listed amongst the key factors (Prunier, 2009; Vlassenroot and Raeymaekers, 2004).

The first Congolese war (1996–1997) started when Laurent Désiré Kabila, heading the Alliance des Forces Démocratiques pour la Libération du Congo (AFDL) and supported by the foreign governments of Rwanda, Uganda, and other neighbouring countries, contested Mobutu's leadership. The second Congolese war (1998–2003) had an even more international dimension because rival countries and factions saw in the conflict-hit DRC a convenient ground for waging proxy wars. Although the end of the second war meant a retreat of international actors from the battlefield, it did not lead to the dissolution of the numerous rival armed groups and gangs that had formed over the course of the seven years of war. In fact the violence in DRC continues to affect the country's stability, especially in its eastern regions.

Congo's natural wealth in mineral resources has been consistently blamed as the main driver of the violence, either as a way to finance warring parties or as a warfare objective in itself (Congdon Fors and Olsson, 2004; Turner, 2007; International Alert, 2010; Gambino, 2011; Stearns, 2011). Although Austesserre (2012) warns about the dangers of focussing exclusively on the role of mineral exploitation as a cause of violence in the country, it is hardly deniable that many Congolese mining locations have been looted and the minerals exported illegally over the years by both Congolese and foreign armed groups (Montague, 2002; Congdon Fors and Olsson, 2004; Prunier, 2009; Freedman, 2011).

The anecdotal evidence is extensive. Over the years the United Nations has repeatedly issued reports of experts, of the UN Security Council, and of the UN Secretary General underscoring that natural resources have shaped and fuelled the conflicts in DRC. There is evidence that both foreign and Congolese armies were directly involved in large-scale looting of mineral resources: regular soldiers were reported to force the mines' managers to 'open the coffers and doors. The soldiers were then ordered to remove the relevant products and load them into vehicles' (Stearns, 2011). Valuable minerals are reported to have motivated the military intervention of neighbouring countries such as Burundi, Rwanda, and Uganda, especially after the end of the first Congolese war. Stearns (2011, p.297) reporting the interview of a pilot highly involved in military and mineral transportation during the Congolese wars observes how 'Rwanda's shifting priorities [between the security imperative during the first Congolese war and the business objectives during the second] became clear to [the pilot who was interviewed] in his flights. He flew their troops into mining areas, where Rwandan commanders would be in charge of loading tons of tin and coltan [a high-value mineral used in the manufacturing of electronic devices] into airplanes'.

The Ituri district provides another good example of the dynamics around the control of minerals. Three main armed groups were actively contesting the control of the local gold deposits: the Union des Patriotes Congolais (UPC), the Front des Nationalistes et Intégrationnistes (FNI), and the Forces Armées du Peuple Congolais (FAPC). According to International Alert (2010, p.30), ‘The FAPC and the FNI clashed over the control of Djalasiga. The UPC held Mongbwalu up until 2003 and were then replaced by the FNI, who were succeeded by the first brigade of the FARDC [the Congolese Army] to be deployed in Ituri. [...] It should be recalled that in their first deployment in Ituri in 2005, the Congolese Army immediately established itself at the mining sites of Mongbwalu and Bambu, from where they drove off the local militia by force, with no regard for the local civilian population.’

3. Baseline analysis

3.1 Data

The empirical analysis is based on the monthly variations of two variables. First, the dependent variable is the monthly sum of conflict events by territories or districts, as recorded in the Armed Conflict Location and Event Data (ACLED) (Raleigh *et al.*, 2010). More than 3,000 conflict events occurred from January 1997 to December 2007, including 2,627 violent events. Figure 1 shows that most conflict events are concentrated in Orientale and North and South Kivu provinces, followed by the territory of Pweto in the Katanga province and Kinshasa. The geographical dispersion of the data tracks the degree to which various areas of the DRC have been affected by conflict, thus giving us confidence regarding the data quality. The relevance of Kinshasa is explained by the strategic and political importance of the capital city in the Congolese conflicts.

Over time, the evolution of conflict events exhibits large monthly variations. As illustrated in Fig. 2, several peaks can be observed in May 1997, January 2001, June 2003, November 2005, January 2006, December 2006, and in particular, August 1998, November 1999, January 2000, and October 2008. Conflict events occurring after 2007 are not included in our sample due to other data constraints. The conflict trend based on ACLED data tracks well-documented increases of violence in DRC reported by secondary literature (see, e.g., Turner, 2007).

We further validate our dependent variable by comparing the distribution of ACLED conflict events with the number of conflicts recorded in the Uppsala Conflict Data Program’s (UCDP’s) Georeferenced Events Datasets (Sundberg *et al.*, 2010). The UCDP data adopt a more restrictive definition of conflict events and only comprise events reporting at least one direct death. Over the period investigated, there have been 967 conflict events recorded by UCDP in contrast with 2,627 violent events in the ACLED data set. Despite the difference of coding, the geographical distribution of UCDP conflict events in Fig. 3 provides a fairly similar picture to the one depicted in Fig. 1. In one of

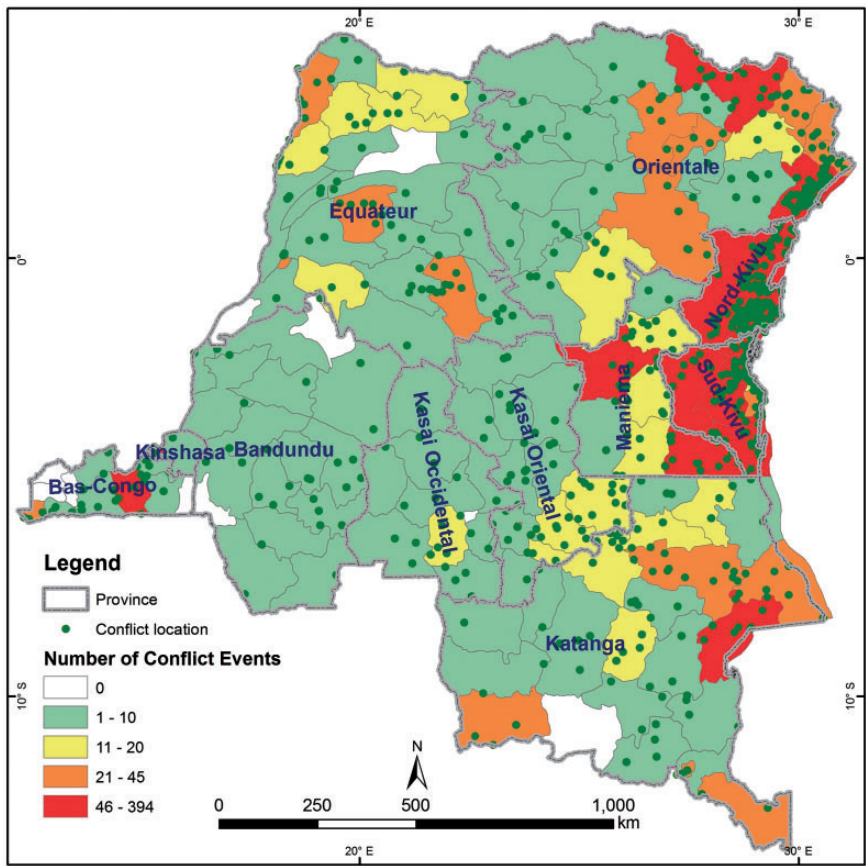


Fig. 1 Distribution of ACLED conflict events in the DRC, 1997–2007

Note: Points represent the raw ACLED events.

Source: Authors' construction based on ACLED data (Raleigh *et al.*, 2010).

our robustness checks we show that our main results are qualitatively identical when using UCDP conflict data.

Second, the main variable of interest relates to the mining concessions. Based on data provided by the Ministry of Mining (5,549 mining concessions granted over the period), we construct the monthly sum of mining concessions granted by territory or district. We will also use the size of these new concessions as an alternative proxy. The minerals involved include gold, copper, diamonds, lead, silver, tin, zinc, palladium, tungsten, and iron ore. There are several types of mining concessions with different permits and associated fees. Due to sample size limitations, we do not distinguish between the two broad categories: research and exploitation. The research permit confers to its owner the exclusive right to conduct, within the scope of which it is established and for the duration of its validity, the research work of the mineral substances classified as mines for which the permit is

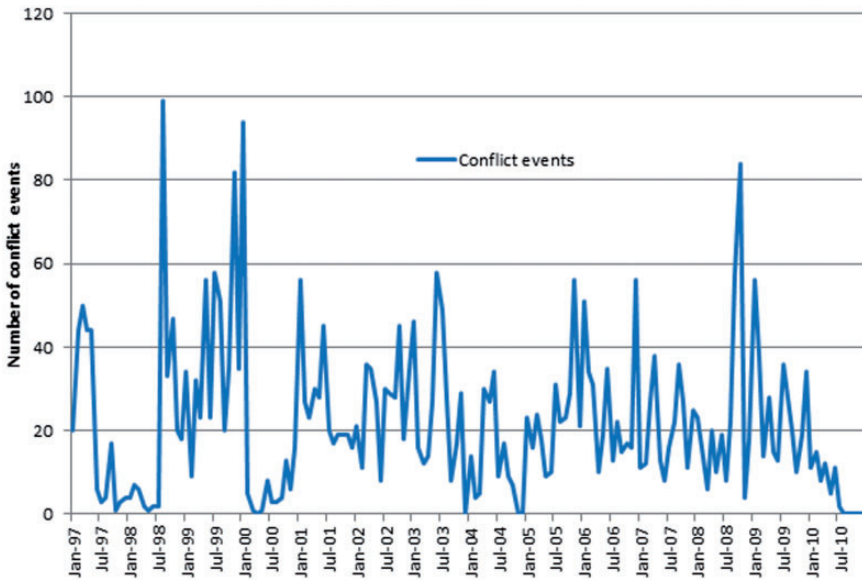


Fig. 2 Number of ACLED conflict events in the DRC, 1997–2010)

Source: Authors' construction based on ACLED (Raleigh *et al.*, 2010).

granted. The permit of exploitation gives its owner the exclusive right to perform, inside the perimeter on which it is established and for the duration of maximum 30 years, the research, development, construction, and exploitation of minerals for which the permit is established. A logarithm transformation is applied to the concession-related variables (adding the value 0.1 when there is no concession) to ease interpretation, although results are still robust without such transformation. In our database, concessions were granted in 1968, 1969, 1970, 1986 and between 1994 and 2007. Figure 4 indicates that mining concessions are mainly granted in eastern and southern DRC, which is consistent with the geological conditions of the country. Visually comparing Figs 1, 3, and 4 suggests that mining concessions may be spatially correlated with conflict.

The nature of the relationship studied in this work requires some caution due to the intrinsic data limitation. First, conflict events may be measured with error. For instance, it is not unlikely that events in very insecure areas have received little news coverage, leading to an underestimation of violence in the most affected areas (Verpoorten, 2012). We run our analysis with the most widely used data set on African conflicts and validate our results by checking the robustness of our finding to the adoption of the alternative UCDP dataset. Second, the cadastral mapping of property rights and mineral concessions may also be inaccurate. This would lead to measurement errors in the mining concessions data. We cannot exclude, for instance, that more stable regions feature a more accurate registration of mineral concessions. The instrumental variables (IV) strategy we employ, described in details in the next section, partly corrects for this.

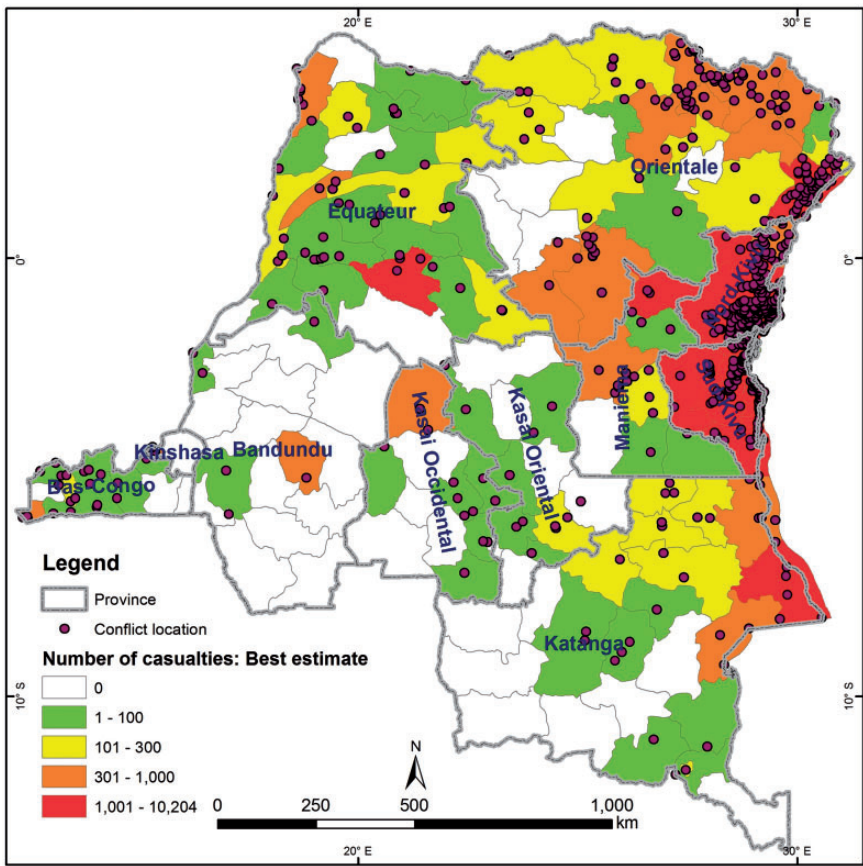


Fig. 3 Distribution of UCDP conflict events in the DRC, 1997–2007

Note: Points represent the UCDP events.

Source: Authors’ construction based on UCDP (Sunderg *et al.*, 2012).

Finally, following Miguel *et al.* (2004), we control for rainfall as a measure for the climate-induced changes in agricultural income in poorly irrigated countries. Agriculture is likely to represent the default economic activity for the vast majority of the population in DRC. Consequently, changes in agricultural income may affect both the incentives for individuals to join armed groups and the profitability of mining via the labour market. Rainfall data are measured by the National Aeronautics and Space Administration (NASA) using a one degree latitude-longitude grid. We follow a standard approach of transforming rainfall data into ‘anomalies’, that is, deviations from normal rainfall conditions. More specifically, the anomalies are computed at the unit of observation (territory or district) and measure the deviations from the long-term monthly mean, divided by its monthly long-run standard deviation. A positive (negative) anomaly therefore signals abnormally high (low) rainfall. The monthly basis is chosen to correct for

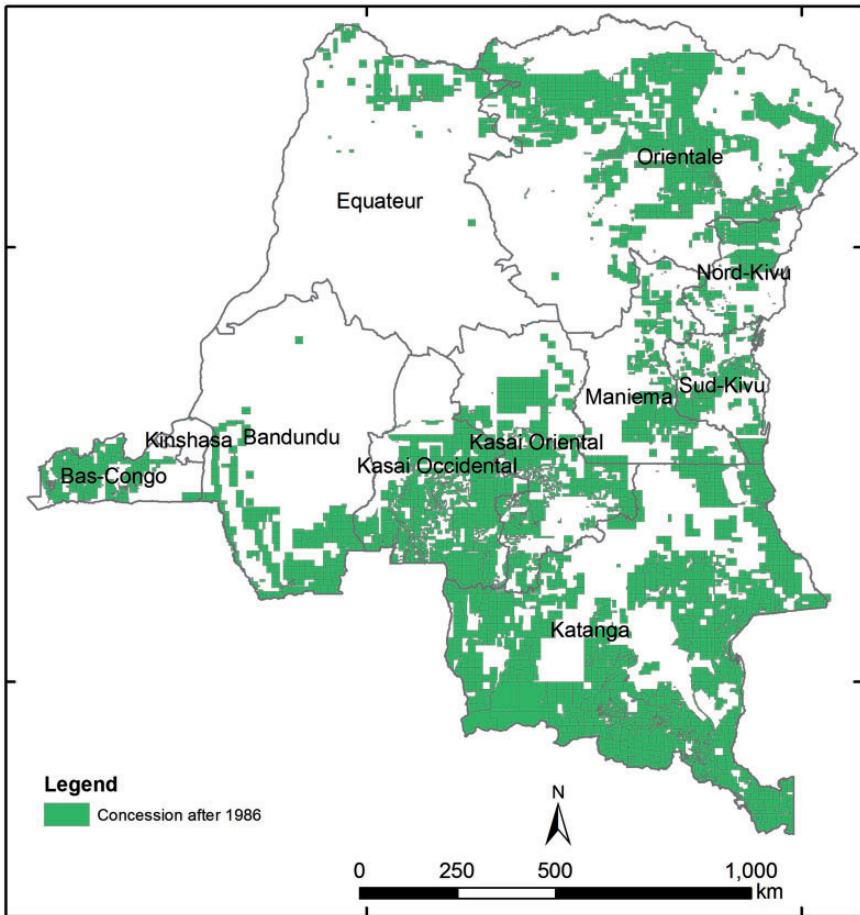


Fig. 4 Distribution of mining concessions in the DRC

Source: Authors' construction based on DRC Ministry of Mining data.

seasonality patterns of rainfall data, whilst the long-run period is defined by the longest period of available data (1997–2010). We introduce the quadratic term of rainfall anomalies to allow for a detrimental effect of excessive rainfall deviations as compared to the normal conditions. Our central results depend neither on the inclusion of rainfall anomalies nor on its quadratic term.

Table 1 provides the descriptive statistics of these variables. Given the relatively long time period used, the non-stationary nature of our variables may be a point of concern, leading to possible spurious relationships (Maddala and Wu, 1999). We perform the Fisher panel data unit root test on the dependent and the explanatory variables (see Table 2). The tests reject the null hypothesis that the series in the panel contain a unit root. All series are stationary at any reasonable level of confidence.

Table 1 Descriptive statistics

Variable	Territory					District				
	Obs	Mean		Min.	Max.	Obs	Mean		Min.	Max.
Conflicts	19800	0.154	1.024	0	41	5016	0.6064	2.443	0	43
Violent Conflicts	19800	0.133	0.960	0	41	5016	0.524	2.242	0	43
Concessions	19800	0.280	1.756	0	46	5016	1.106	5.467	0	103
Rainfall Anomalies	19800	1.08E-09	0.953	−2.77	3.004	5016	−3.09E-09	0.916	−2.5	2.99
Price Index	19650	506.02	2965.6	0	57774.8	4978	1997.5	7107.3	0	63507.3

Note: The prices of copper, nickel, zinc and lead are not available for one particular month, i.e., April 1998. That explains the slight reduction of observations for the price index compared to other variables.

Table 2 Panel unit root test

Level of Analysis	Territory	District
Conflict Number	6470.2***	1489.46***
Violent Conflict	6432.27***	1503.91***
(Log) Concessions	4390.79***	1035.36***
Price Index	0.193	0.174

Note: *** $p < 0.01$.

3.2 Identification strategy

Our analysis exploits monthly (t) and geographical (i) variations in the occurrence of conflict events ($Conflicts_{i,t}$) and granting of mining concessions ($Concessions_{i,t}$) between January 1997 and December 2007 to draw causal inference on the role of new or future mining activities on the level of violence in DRC. The period under investigation is dictated by data availability, which implies that our analysis is limited to the incidence of local conflict events rather than on the onset of the first Congolese war (end of 1996). Using sub-national within-variations, we are mainly capturing the local dynamics of the relationship between mining concessions and conflicts whilst failing to capture the wider geopolitical dimensions. Ideally we would like to estimate the following equation:

$$Conflicts_{i,t} = \alpha_i + \alpha_t + \beta Concessions_{i,t} + \epsilon_{i,t} \tag{1}$$

Yet despite the introduction of territory/district fixed effects (α_i) and a series of month-year time dummies (α_t), in estimating eq. (1) we are likely to face severe endogeneity problems (Brunnschweiler and Bulte, 2008, 2009). In our case, granting mineral concessions may be highly endogenous because of simultaneity as mining companies might be less likely to invest in conflict-prone areas, or because of omitted factors since the granting of concessions may be driven by local politics that could equally directly influence the occurrence of conflict. In addition, measurement problems for conflict events and in the cadastral data are likely to correlate with conflict events, thereby introducing additional biases. To deal with these

methodological challenges, our estimation relies instead on an IV strategy similar to Brückner and Ciccone (2010). We exploit historical concessions coupled with changes in international prices of minerals to assess the causal relationship between mining concessions and conflict. Historical concessions are defined as those granted before 1986. Mineral-specific international prices are taken from the United Nations Conference on Trade and Development's commodity price statistics and are normalized.⁴ A price index is then constructed by interacting the number of past concessions of mineral j in location i ($PastConc_{i,j}$) with the time-varying international prices of the mineral j the mining concessions extract or aim at extracting ($P_{j,t}$). The constructed index may be expressed as follows:⁵

$$PriceIndex_{i,t} = \sum_j PastConc_{i,j} P_{j,t}$$

The two-stage least squares estimation is implemented at two geographical levels of analysis, the territory and the district levels. A linear specification is adopted as non-linear methods in a two-stage framework imply strong specification assumptions (Angrist and Krueger, 2001). Accordingly, our estimating equations are the following:

$$\begin{aligned} Conflicts_{i,t} &= \alpha_i + \alpha_t + \beta_1 \widehat{Concessions}_{i,t} + \beta_2 Rainfall_{i,t} + \epsilon_{i,t} \\ Concessions_{i,t} &= \alpha'_i + \alpha'_t + \gamma_1 PriceIndex_{i,t} + \gamma_2 Rainfall_{i,t} + \epsilon_{i,t} \end{aligned}$$

We add rainfall anomalies ($Rainfall_{i,t}$) to control for changes in the opportunity cost to fight that are unrelated to mining concessions. To control for other unobserved factors, our estimates introduce territory/district fixed effects (α_i) and a series of month-year time dummies (α_t).

The use of time-varying international prices, coupled with historical concessions, provides an exogenous shock on the probability to grant a new mining concession of a particular mineral type. The rationale for using international prices as an exogenous variation is that conflicts in one particular territory or district of the DRC cannot alone affect the international prices of these minerals.⁶

Changes in international prices instead do affect the demand for mining concessions: an increase in international prices should increase the attractiveness of

⁴ If reported to be traded on different markets in the UNCTAD data set, we select the US market as the international reference. The prices are normalized to 100 for the first month of 1997. The prices of copper, nickel, zinc, and lead are not available for April 1998, which explains the slight reduction of observations for the price index compared to other variables (see Table 1).

⁵ Notice that similar results are found when the price index is expressed as a proportion, that is, when $PastConc_{i,j}$ is divided by $\sum_j PastConc_{j,t}$.

⁶ The price of coltan is excluded from the construction of the price index to ensure the exogenous nature of the price index as an instrument. DRC is indeed one of the major coltan producers, producing in 2001 about 4% of the world production (Roskill Information Services, 2002). However, the results remain unaltered when the price of coltan is included in the price index. In that case, coltan prices are derived from Roskill Information Services (2002) and the US Geological Survey. We thank Olivier Dagnelie for sharing that data.

obtaining a new mining concession, given higher expected revenues. This is particularly true in areas where concessions of similar minerals have been granted in the past. The reasons may be related not only to the physical presence of these minerals but also to the investments needed to exploit these minerals, such as investments in infrastructure, as well as the local labour market conditions, the existing contractual arrangements, and so on. Anecdotal evidence suggests that changes in prices may have an immediate effect on mining exploitation and demand for concessions.⁷

Our identification strategy relies on the validity of our instrumental variable. Although the relevance of that instrument may be directly tested, the exclusion restriction may be questioned. We assume the constructed price index to be uncorrelated with the error terms, which implies that this index affects conflicts exclusively through the contemporaneous granting of concessions. Asserting that the international prices of minerals are exogenous is a reasonable assumption.

Our exclusion restriction, however, also requires that the unobserved political discretionary rules affecting the granting of mining concessions are different for the more recent mining concessions under Laurent Désiré Kabila and his son Joseph (1997–2007) and for the historical concessions granted under Mobutu's regime. Notice first the different geographical origin of the leaders (Orientale province for Mubutu and Katanga province for Kabila) and their ethnic origin (Ngbandi for the former and Luba for the later), suggesting that the rules of discretion in the granting of concessions are unlikely to have been the same over the two periods. Anecdotal evidence on the way mining concessions have been granted in the two periods seems to support our exclusion restriction. Under Mobutu, the mining sector was entirely nationalized and mining concessions were largely under the control of the centralized and authoritarian regime. Mining revenues were used to 'fund Mobutu's patronage network instead of reinvesting earnings into infrastructure and development' (Stearns, 2011, p.289). The rules of the game changed in 1995 when Mobutu allowed his prime minister, Kenga wa Dondo, to gradually privatize the mining sector. In 1997, 'the rebellion [led by Laurent-Desire Kabila] applied its half-Marxist, half-liberal approach to mining, adopting a slipshod policy that imposed harsh conditions on large foreign companies while favouring shadowy investors who often lacked the resources and expertise necessary to develop mining concessions' (Stearns, 2011, p.290).

Finally, the economic conditions surrounding the mining concessions experienced important changes between the two periods. In the early years of Mobutu, characterized by high prices for copper, gold, and cobalt, the mining sector was the largest source of employment and income in DRC. In the 1990s, low international prices for key exported minerals coupled with years of mismanagement dampened the profitability of mining activities. 'Exports declined from a

⁷ For example, *The Economist* reports how mining companies came from all over the world to deal with the Governor of Katanga, home to about 5% of the world's copper and nearly half its cobalt, following the record rises in prices for these minerals (*The Economist*, 2011).

high of 465,000 tons in 1988 to 38,000 tons just before the war, while cobalt production slipped from 10,000 to 4,000 tons in the same period. Similar trends affected all other mineral exports' (Stearns, 2011, p.289).

3.3 Empirical results

In Table 3, we report the results of a simple ordinary least squares (OLS) and the two-stage least squares estimation as described in the preceding section.⁸ Notice first that a naive OLS regression largely underestimates the relationship between mining concessions and conflict and results in a non-significant negative relationship. The downwards bias suggests that all else equal, mining companies are looking for locations where conflict is less likely to occur.

Moving to the IV model, at both levels of analysis (territory and district), the price index appears to be highly relevant: it strongly and positively affects the probability of granting a mining concession. The *F*-test on excluded instruments allows us to unambiguously dismiss the risk of weak instruments. We also use a just-identified equation, which is known to be approximately unbiased. When we run our analysis at the territorial level we find no evidence for granted mining concessions to affect the risk of conflict (regressions (3) and (4) of Table 3). At the district level, however, the instrumented mining concessions significantly increase the risk of conflict, and in particular of violent conflicts (regressions (7) to (8) of Table 3). The magnitude of the effect is substantial: at the district level, given the mean number of conflict events reported in Table 3, a 10% increase in the number of mining concessions would increase the likelihood of conflict by about 29%.⁹ Adopting standard errors clustered at the district/territory level does not affect the results.

We examine the solidity of these findings by implementing three different sets of robustness test. All results are condensed in Table 4, where we report only the coefficient for concessions in the second stage. The first stage (not reported) is always significant, and all models control for rainfall anomalies, year month fixed effects, and district/territory fixed effects.

First, we assess the importance of specific locations and conflict periods in establishing our results. Indeed, our findings may be mainly driven by the very high concentration of violent events in some territories/districts. A first concern is that the violence in Kinshasa depicted in Fig. 3 may capture another channel, such as the strategic value of the capital or the increased state capacity following price-induced changes in mining revenue. In row A of Table 4 we show that our findings are robust to the exclusion of the capital district (or the two corresponding territories), Kinshasa, from the sample. A different concern is that our results are not sufficiently representative of the entire country because they could be driven by the

⁸ In the Supplementary Material we provide more parsimonious specifications of both models, without fixed effects, without rainfall variables.

⁹ This effect is computed based on regression (7) of Table 3.

Table 3 Baseline results: a case of ecological fallacy

Level of analysis	Territory		District					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	OLS	OLS	2SLS	2SLS	OLS	OLS	2SLS	2SLS
	Conflicts	Violent conflicts	Conflicts	Violent conflicts	Conflicts	Violent conflicts	Conflicts	Violent conflicts
(Log) Concessions	-0.00778 (0.00795)	-0.00694 (0.00763)	-0.104 (0.165)	0.0133 (0.137)	-0.0351 (0.0327)	-0.0298 (0.0314)	1.752** (0.802)	1.640** (0.718)
Rainfall anomalies	-0.0260*** (0.00836)	-0.0222** (0.00868)	-0.0249** (0.00989)	-0.0232** (0.00924)	-0.0953** (0.0433)	-0.0820** (0.0399)	-0.162** (0.0633)	-0.144** (0.0582)
Rainfall anomalies ²	0.000405 (0.00658)	0.000471 (0.00626)	-0.000129 (0.00596)	0.00105 (0.00558)	0.0150 (0.0234)	0.0114 (0.0235)	0.0776 (0.0490)	0.0698 (0.0457)
Territory FE	✓	✓	✓	✓	✓	✓	✓	✓
Year Month FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	19,800	19,800	19,650	19,650	5,016	5,016	4,978	4,978
Root MSE		0.98	0.98	0.92			2.81	2.61
Underid test		24.20***	24.20***	24.20***			26.99***	26.99***
Territories/Districts	150	150	150	150	38	38	38	38
First stage			(Log) Concessions	(Log) Concessions			(Log) Concessions	(Log) Concessions
Price index			4.73e-05*** (8.31e-06)	4.73e-05*** (8.31e-06)			4.6e-05*** (7.45e-06)	4.6e-05*** (7.45e-06)
R-squared			0.210	0.210			0.306	0.306
F-test			12.11***	12.11***			7.19***	7.19***
F-test on excluded IV			32.37***	32.37***			38.97***	38.97***

Notes: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$. The F -test statistic on excluded IV is equal to the Kleibergen-Paap rk Wald Statistic in a just-identified equation. That Wald F Statistic is much higher (at least, twice) than the Stock-Yogo critical value corresponding to a maximal IV size of 10%.

mining-related violence occurring in eastern DRC and in particular in the region of Kivu (North and South Kivu provinces). We re-run our two-stage fixed effect estimation, excluding the Kivu region from the sample (see row B of Table 4). The magnitude of the coefficients is reduced as a consequence of the conflict intensity in the Kivus, but the significant positive effect obtained at the district level is confirmed. Mining activities and violence occurring in North and South Kivu are clearly important to explain the role of mining resources in fuelling conflict, but the results are also valid for other parts of the country. Our results are also robust to the exclusion of any individual province from the sample.¹⁰ A related concern is whether the link we identify between mining and conflict describes the entire period of violence in DRC. Our results in row C of Table 4, in which we restrict the analysis to the period after the signing of the official peace agreement in June 2003, suggest that mineral resources continue having a substantial role in shaping violence after the termination of two official Congolese wars.

The second set of robustness checks addresses the validity of the exclusion restriction. Beyond the qualitative arguments given in the previous section on the reasonable nature of our identifying assumption, we alter the sample to assess more directly the validity of that assumption. One potential concern is that changes in international prices may revive mining in historical concessions as well, thereby affecting nearby conflict. This would then constitute a different channel than the granting of new concessions and it would endanger our exclusion restriction. We know that concessions are granted for a maximum of 30 years. We therefore check the robustness of our results to the exclusion of the territory/district affected by the granting of a concession in 1986 and to limiting the sample to the post-April 2000 period (30 years after the last concession granted in 1970). The results, reported in rows D and E of Table 4, remain qualitatively identical.

Third, our results are robust to alternative definitions of the main variables of interest and of the dependent variable (rows F to J of Table 4). First, if we repeat our estimation using the logged size of the concessions (instead of the number of concessions), we obtain qualitatively identical results. Second, not proceeding to the logarithmic transformation of the concessions variable or adopting the alternative definition of the mining concessions evaluated on the basis of the year of demand (instead of the year of granting), does not affect our findings either. As for the dependent variable, our results are robust to the adoption of the UCDP conflict database, which records conflict events with at least one death. Similarly, qualitatively identical results are obtained when the dependent variable is replaced by a dummy variable indicating whether the concerned geographical unit records at least one conflict event for one particular month (consequently using a linear probability model). Finding similar results with the linear probability model suggests that the number of mining concessions may also affect the “extensive margin” of conflicts, following similar mechanisms as the “intensive margin” of conflicts.

¹⁰ Results provided on request.

Table 4 Robustness checks on the ecological fallacy

Level of analysis	Territory		District	
	(1)	(2)	(3)	(4)
Dependent variable	Conflicts	Violent conflicts	Conflicts	Violent conflicts
A: Excluding Kinshasa	−0.111 (0.166)	0.0118 (0.138)	1.759** (0.811)	1.659** (0.728)
B: Excluding Kivus	0.0402 (0.0442)	0.0416 (0.0432)	0.142** (0.0647)	0.114* (0.0603)
C: Sample after June 2003	0.139 (0.0858)	0.120 (0.0791)	1.529** (0.711)	1.346** (0.619)
D: Dropping 1986 concessions	−0.113 (0.180)	0.0139 (0.150)	1.759** (0.811)	1.659** (0.728)
E: Dropping 1986 concessions and observations before March 2000	0.0426 (0.162)	0.109 (0.141)	1.382* (0.761)	1.285* (0.682)
F: Concessions size (log)	−7.32e-10 (1.16e-09)	9.36e-11 (9.69e-10)	0.642** (0.290)	0.601** (0.260)
G: Demand for concessions	0.825 (2.689)	−0.809 (2.296)	1.541** (0.704)	1.442** (0.632)
H: Non logged concessions	−0.0853 (0.136)	0.0109 (0.113)	0.630* (0.363)	0.590* (0.330)
I: Using UCDP conflict data	0.0889 (0.0543)		0.885** (0.361)	
J: Conflict dummy (=1 if any conflict event recorded)	−0.0166 (0.0462)	0.0185 (0.0432)	0.107** (0.0475)	0.117** (0.0486)

Notes: Only the coefficients for *concessions* in the second-stage regressions are reported. Coefficients of the instrument of the first-stage regressions are always significant. All regressions control for territory/district FE, year month FE, rainfall anomalies and square rainfall anomalies. Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In sum, we find robust evidence that mineral concessions significantly increase the likelihood of violence at the district level, whilst no evidence is found for such a link at the territory level. This result constitutes a case of ecological fallacy or aggregation problem, that is, a misleading assumption that the relationship observed at an aggregated level (e.g., district) implies the same relationship at a different level of aggregation (e.g., territory). In the next section, a simple theoretical model is geared to explain this puzzling finding.

4. Theoretical framework

We consider a region represented by a unit-length line inhabited by a uniformly distributed continuum of individuals of unit mass. These individuals are each endowed with a unit amount of time. We assume without loss of generality that all concessions are located at the line’s origin. Concessions operating in the region belong to a mine-extraction company controlled by incumbent i . A challenger c endeavours taking over the region hosting the mining concessions by violent

means. We model the externality of the ensuing conflict on the mining business as an increased cost of inputs.

Labour constitutes the unique input of the mining activity, and we assume that the mining company is a local monopsonist on the labour market. The profits from controlling the mining concession, π , read as follows:

$$\pi(x_m, d_v; A) = (\phi(x_m) - y_m(x_m, d_v))nx_m \quad (2)$$

where ϕ is the unit return to labour when employed in mining, which we assume concave in the number of workers active in the mine, x_m . The parameter n captures the number of mining concessions. The workers are remunerated at the (endogenous) wage of y_m . The monopsonist will therefore determine the demand for mining labour. Individuals specialize in mining or farming. The number of farmers is denoted by $x_f = 1 - x_m$. The farming activity yields an income y_f . Mining is remunerated at the wage y_m , yet the miners have to incur the unit commuting cost of $(1 - d_v)\tau$ to reach the mining company from their initial location, where d_v is the distance of conflict from the location of the mine. An individual k located at a distance d_k from the mine prefers working in the mining sector instead of farming if $y_m \geq y_f + (1 - d_v)\tau d_i$. Notice that the proximity of conflict to the mining sites increases the commuting cost for miners, thereby reducing their net wage.

The incumbent maximizes his payoff with respect to three choice variables: (i) the number of miners x_m ; (ii) the amount of soldiers to deploy against the challenger, x_i , given the exogenous unit cost \bar{y} of the soldiers¹¹; and (iii) the location of its army, d_v , given an increasing and convex deployment cost $c(d_v)$.¹² We describe the probability that the incumbent beats the challenger by the function $p(x_i, x_c, d_v)$, with x_c standing for the challenger's number of soldiers, and the fighting technology satisfying some very general assumptions:

$$p(x_i, x_c, d_v) = \frac{g(x_i)e(d_v)}{e(d_v)g(x_i) + g(x_c)}, g'(x_i) > 0, g''(x_i) < 0, e'(d_v) > 0, e''(d_v) < 0, j = \{i, c\}$$

The probability that the incumbent is victorious in a confrontation with the challenger is assumed to depend positively on the incumbent's army strength $g(x_i)$, and on his relative fighting efficiency $e(d_v)$, whereas it is a negative function of the challenger's strength $g(x_c)$. Moreover, we are assuming that the incumbent's relative fighting efficiency is the highest when his troops are deployed close to the incumbent's headquarters and that this fighting efficiency is monotonically decreasing in d_v .

Notice that deploying the army farther from the mines has three effects: first, it decreases the cost of labour (as it increases the net wage offered to miners); second,

¹¹ Making the fighters' remuneration endogenous would unnecessarily complicate the model. Indeed, having assumed that the pool of workers is not influenced by the number of fighters recruited, the endogenous remuneration of the latter would simply amount to a rescaling of our results.

¹² All results remain qualitatively unchanged if the deployment cost is linear.

it increases the costs of deployment, $c(d_v)$; and third, it reduces the efficiency of fighting of the army, as soldiers have to patrol a larger territory.

The utility of the incumbent is therefore given by:

$$u_i = p(x_i, x_c, d_v) \pi(x_m, d_v) - \bar{y}x_i - c(d_v) \quad (3)$$

Since the labour force, x , has two occupational choices and the commuting cost, τ , is incurred by the workers, it follows that for a mining wage y_m , any individual lying on the interval $[0, d_m]$ prefers mining to farming, where d_m is defined as:

$$d_m = \frac{y_m - y_f}{\tau(1 - d_v)}$$

We thus have the mining labour supply as follows:

$$x_m^s = \begin{cases} \frac{y_m - y_f}{\tau(1 - d_v)} & \text{if } \frac{y_m - y_f}{\tau(1 - d_v)} \leq 1 \\ 1 & \text{otherwise} \end{cases}$$

It then follows that the inverse labour supply function is given by:

$$y_m = \begin{cases} \tau x_m(1 - d_v) + y_f & \text{if } x_m^s \leq 1 \\ \tau(1 - d_v) + y_f & \text{otherwise} \end{cases}$$

We can now write the incumbent's maximization problem as follows:

$$\max_{x_m, d_v, x_i} \left\{ \frac{g(x_i)e(d_v)}{e(d_v)g(x_i) + g(x_c)} [\varphi(x_m) - \tau x_m(1 - d_v) - y_f] n x_m - \bar{y}x_i - c(d_v) \right\} \quad (4)$$

Optimizing yields the following first-order conditions:

$$\frac{\partial u_i}{\partial x_m} = p(x_i, x_c, d_v) n (\varphi(x_m) - y_f + \varphi'(x_m)x_m - 2\tau(1 - d_v)x_m) = 0 \quad (5)$$

$$\frac{\partial u_i}{\partial d_v} = \frac{e'(d_v)g(x_i)g(x_c)}{(e(d_v)g(x_i) + g(x_c))^2} \pi(x_m, d_v) + p(x_i, x_c, d_v) \tau n x_m^2 - c'(d_v) = 0 \quad (6)$$

$$\frac{\partial u_i}{\partial x_i} = \frac{g'(x_i)g(x_c)e(d_v)}{(e(d_v)g(x_i) + g(x_c))^2} \pi(x_m, d_v) - \bar{y} = 0 \quad (7)$$

We show in the [supplementary material](#) that the incumbent's utility function is quasi-concave in the decision variables.

The challenger's optimization problem is analogously given by:

$$\max_{x_c} \left\{ \frac{g(x_c)}{e(d_v)g(x_i) + g(x_c)} \pi(x_m, d_v) - \bar{y}x_c \right\} \quad (8)$$

Optimizing gives the following first-order condition:

$$\frac{\partial u_c}{\partial x_c} = \frac{g'(x_c)g(x_i)e(d_v)}{(e(d_v)g(x_i) + g(x_c))^2} \pi(x_m, d_v) - \bar{y} = 0 \quad (9)$$

It is straightforward to show that the challenger's objective function is concave in x_c .

Having shown that the problem is well behaved, we can deduce that a Nash equilibrium for this game exists (see Mas-Colell *et al.*, 1995, proposition 8.D.3). Moreover, by combining eqs (7) and (9), we can deduce that $g'(x_i)g(x_c) = g'(x_c)g(x_i)$, and since $g(\cdot)$ is a concave function it is necessary that $x_i = x_c$. Equipped with these results, we can now conduct comparative statics on the parameter of interest.

4.1 Comparative statics

Using eq. (5) and by the Implicit Function Theorem we can derive the following expression:

$$\frac{dx_m^*}{dn} = - \frac{p(x_i, x_c, d_v) \partial \pi(x_m, d_v) / \partial x_m}{\frac{\partial^2 u_i}{\partial x_m^2}} \quad (10)$$

The numerator is nil, as it equals the first-order condition in eq. (5) up to a multiplicative term n . Because the number of concessions n linearly affects the profitability of mining, changing the number of the mining concessions does not affect the optimal number of miners: both the marginal cost of hiring an additional worker, and his marginal return for the company are unaffected by the increase in n . This does not mean, however, that the industry has not become more profitable, rather, the incumbent will see his profits increase proportionally to the number of mines he controls.

Proceeding likewise with condition (6) we obtain:

$$\frac{dd_v^*}{dn} = - \frac{p(x_i, x_c, d_v) \left(\frac{e'(d_v)g(x_c)}{e(d_v)g(x_i) + g(x_c)} \pi(x_m, d_v) / n + \tau x_m^2 \right)}{\frac{\partial^2 u_i}{\partial d_v^2}} > 0 \quad (11)$$

Using the first-order condition in eq. (6), we deduce that the numerator of eq. (11) is equal to expression (6) to which we subtract its third term and divide the whole expression by n , thus implying that the numerator of eq. (11) is positive and that $\partial d_v^* / \partial n > 0$.

The net effect of an increase in the number of concessions on the optimal location of conflict is the result of two opposing forces. On the one hand the incentives to protect a resource that has become more valuable are higher, thus pushing the incumbent to wage conflict further from the mining location so that the mining activity is less disrupted. On the other hand, however, the same force induces the incumbent to reduce the distance of combat to the mine so that his troops' efficiency is enhanced. Eventually, since the marginal cost of troop deployment is unaffected by an increase in the number of mining sites, it follows that the marginal benefit from moving the conflict further from the mining location outmatches the marginal cost in terms of forgone fighting efficiency.

Finally, we can derive the effect of a change in n on the intensity of conflict by using eq. (7):

$$\frac{dx_i^*}{dn} = -\frac{g'(x_i)g(x_c)e(d_v)}{(e(d_v)g(x_i) + g(x_c))^2} \frac{\partial \pi(x_m, d_v)/\partial n}{\frac{\partial^2 u_i^*}{\partial x_i^2}} > 0 \quad (12)$$

The sign of this expression is as expected, since the marginal benefit of additional soldiers on the ground follows the increase in mining profits, whilst the marginal cost of this operation remains unchanged. As a consequence the incumbent will deploy more troops, and given the strategic complementarity between the forces of the incumbent and those of the challenger, the latter will equally deploy more troops at equilibrium.

5. Revisiting the empirical analysis

Our theoretical model suggests that the impact of mining concessions on conflict is non-homogeneous across space. In particular, increasing the number of mining sites has the potential not only of increasing overall conflict intensity but also of displacing violent events further from mineral deposits. Anecdotal evidence in support for this thesis abounds. The weak state capacity in most of the DRC enabled armed groups, including the FADRC, to profit from minerals not only through direct looting but also by granting protection to mining sites in exchange for a participation to the mining industry's profits (Fessy, 2010; Spittaels, 2010; Raeymaekers, 2010; de Koning, 2011; Verweijen, 2013). This military-turned-businessman formula has been shown to improve local governance (Raeymaekers, 2010; Sanchez de la Sierra, 2013), echoing the works of Gambetta (1993) on the business-promoting consequences of the Sicilian Mafia. According to these accounts, a displacement of violence occurred at times where armed groups would focus their attention on the protection of a particular mining location (Rudahigwa, 2010; UN Presidential Statement S/2010/596, 2010; de Koning, 2011). The following quote from de Koning (2011, p.26) is particularly illuminating:

Clearly the controlling military actor stands to gain by establishing a minimum level of stability in which miners and traders can operate. [...] In this, these actors either mimic the operations of private businesses or operate in partnership with them, offering means of production and transport, as well as a degree of protection. [...] Finally, when driven by economic interests, FARDC troop deployments focus on major mines and trading centres, leaving smaller mines and communities vulnerable to looting by armed groups. According to the UN Group of Experts, a number of villages in Walikale that were looted and where mass rapes took place in early July 2010 had no security presence because FARDC units in the area were competing for control of the Bisie mines.

A recent study of Sanchez de la Sierra (2013) provides micro-founded evidence that rises in mineral prices incentivize armed groups to better protect and tax at the local level in eastern DRC, hence unveiling a sort of proto-state building. Such

decentralized development of state capacity is fully consistent with our own theory that we next attempt to highlight by incorporating the spatial dimension in the econometric analysis.

A first empirical indication of such spatial dependency is given in Table 5. The Lagrange multiplier (LM) tests performed in columns (1) to (3) of Table 5 suggest significant spatial lags and error correlations at the territory level.

To explicitly assess the importance of spatial spillovers, we consider two models. First, we assess the role of spatially lagged mineral concessions, following Florax and Folmer (1992). We apply the method to our panel analysis following Anselin (2002). We augment eq. (2) with a spatially lagged explanatory variable in the following way:

$$\begin{aligned}
 Conflicts_{i,t} &= \alpha_i + \alpha_t + \beta_1 \widehat{Concessions}_{i,t} + \beta_2 W\widehat{Concessions}_{i,t} \\
 &\quad + \beta_3 Rainfall_{i,t} + \epsilon_{i,t} \\
 Concessions_{i,t} &= \alpha'_i + \alpha'_t + \phi_1 PriceIndex_{i,t} + \phi_2 WPriceIndex_{i,t} \\
 &\quad + \phi_3 Rainfall_{i,t} + \epsilon'_{i,t} \\
 WConcessions_{i,t} &= \alpha''_i + \alpha''_t + \theta_1 PriceIndex_{i,t} + \theta_2 WPriceIndex_{i,t} \\
 &\quad + \theta_3 Rainfall_{i,t} + \epsilon''_{i,t}
 \end{aligned} \tag{13}$$

We use a distance-based spatial matrix based on the inverse distance decay function. $WConcessions_{i,t}$ and $WPriceIndex_{i,t}$ are weighted sums of the concession-based variables and price indices at other locations. We can, for instance, express the variable $WConcessions_{i,t}$ as follows:

$$WConcessions_{i,t} = \sum_{j \neq i} w_{ij} Concessions_{j,t} \text{ where } w_{ij} = \frac{d_{ij}^{-\gamma}}{\sum_j d_{ij}^{-\gamma}}$$

Where γ takes the values 1 or 2 as these are the most common integers used in spatial econometrics (Anselin, 2002).

Second, we also estimate spatial panel models with time and location fixed effects using Matlab routines and methods developed by Elhorst (2003, 2010). The estimation approach includes the bias correction procedure proposed by Lee and Yu (2011) for spatial panel data models containing spatial and/or time-period fixed effects. Because of the absence of convincing evidence of the presence of spatial correlation at the district level, in addition to possible small sample bias with respect to districts (just 38), we discuss only territory-level estimates.

Estimating the system of eq. (13), Table 6 indicates that at the territory level the granting of mining concessions in the neighbouring territory significantly increases the risk of conflict (especially violent conflicts). The coefficient of the non-spatially lagged variable is negative and significantly different from zero. Table 6 indicates that these results are robust to the use of an alternative spatial matrix of order 1, instead of 2 (regressions (3) and (4) in Table 6). In regressions (5) and (6) of Table 6, we report estimation results using explicit spatial models for panel data

Table 5 Lagrange Multiplier tests for spatial correlations

Level of analysis	Territory		District	
	(1)	(2)	(3)	(4)
Dependent Variable	Conflicts	Violent conflicts	Conflicts	Violent conflicts
(Log) Concessions				
Spatial lag	73.69***	73.69***	3.2	3.8
Spatial error	73.49***	73.49***	2.7	3.4

Note: *** $p < 0.01$.

Table 6 Results with spatial dependency

Order of Spatial Matrix	2		1			
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Conflicts	Violent conflicts	Conflicts	Violent conflicts	Conflicts	Violent conflicts
(Log) Concessions	−0.542** (0.276)	−0.404* (0.234)	−0.911** (0.416)	−0.737** (0.363)	−0.93*** [−8.203]	−0.780*** [−7.408]
(Log) neighbouring concessions	3.337*** (1.102)	3.105*** (1.009)	2.367*** (0.794)	2.175*** (0.740)	2.535*** [12.828]	2.255*** [12.278]
Spatially lagged dep. var.					0.103*** [8.96]	0.094*** [8.145]
Spatial error correlation					0.282*** [12.72]	0.295*** [12.76]
Rainfall anomalies	✓	✓	✓	✓	✓	✓
Rainfall anomalies ²	✓	✓	✓	✓	✓	✓
Territory FE	✓	✓	✓	✓	✓	✓
Year Month FE	✓	✓	✓	✓	✓	✓
Observations	18,000	18,000	18,000	18,000	19,800	19,800
Root MSE	1.147	1.072	1.357	1.248		
Underid test	19.7***	19.7***	15.31***	15.31***		
Log Likelihood					−502	−476
Territories	150	150	150	150	150	150

Notes: *** p_i 0:01, ** p_i 0:05, * p_i 0:1; Robust standard errors in parenthesis; asymmetric T -statistics in brackets.

based on the methods developed by Elhorst (2003, 2010), along with the bias correction procedure proposed by Lee and Yu (2010) for spatial panel data models containing spatial and/or time-period fixed effects. The results suggest the existence of significant spillovers in conflict intensity in both the error term and the spatial dependent variable. In other words, conflicts erupting in territories are not independent from each other; consequently, any strategy to address these conflicts should be comprehensive and inclusive. Even with these spatial

specifications, our estimates remain very stable. Based on regressions (6) of Table 6 and given the mean number of conflict events reported in Table 1, a 10% increase in the number of mining concessions would respectively decrease the likelihood of conflict events by about 60% in the same territory. However, a similar increase in the number of the concessions would also increase the number of conflicts by about 165% in the neighbouring territory. At the district level, no spatial effect is found. As in Section 3.3, results are robust to alternative definitions of the mining concessions and conflict variables and to subsample analyses.

Overall, these results are consistent with the theoretical predictions that a larger number of mining sites increases the protection effect, thereby reducing violence around the mine(s); gives the incentives to the incumbent to move the conflict location farther from the mining site (potentially in a neighbouring territory); and results in a higher level of violence at the aggregate level (adequately captured at the district level). Although caution is usually called for when interpreting spillover effects as causal (Corrado and Fingleton, 2011), the theoretical model developed in the previous section supports such interpretation and allows us to go beyond purely data-analytic considerations. Our results are therefore supportive of the spatially based theoretical mechanisms proposed in the previous section and are likely to explain what appeared to be an ecological fallacy in Section 3.3. In other words, the absence of a statistically significant relationship between mining concessions and (violent) conflicts at the territory level in our baseline regression is driven by an omitted spatial effect, explained by the incumbent's incentives to protect the mining business. When spatial spillovers are taken into account, a mining concession tends to decrease the risk of conflict in the same territory but increases the risk in neighbouring territories. That in turn explains why a change in the number of concessions would translate at a more aggregated effect (that is, the district level) into an increase in conflict intensity.

6. Alternative explanations

In interpreting our empirical results we propose an explanation based on the incentives of extractive companies to protect their business. How does our 'protection effect' mechanism perform against alternative explanations?

Several alternative explanations are compatible with natural resource wealth having a nonsignificant effect on conflict at the very local level and a significant and substantial effect at a higher level of aggregation. The first relates to measurement errors and the potential lack of within-territory variation. Conflict events may be measured with more noise at the territory level as underlying sources may be less accurate about the precise territory in which the event takes place. This would generate relatively larger standard errors in our analysis at the territory level. We cannot completely rule out this explanation. However, repeating the analysis with the two most commonly used geo-referenced data set on conflict (ACLED and UCDP) does not affect our findings. Moreover, this criticism would likewise invalidate a substantial share of recent conflict studies which moved the focus of the analysis

to more disaggregated geographic levels. We also argue that the ecological fallacy cannot be explained by a difference in variations between the two samples. First, our findings in Section 5 show that there is enough variation at the territory level to efficiently estimate the relationship of interest, provided the specification is in line with the theoretical mechanism linking mineral concessions and conflicts. Second, implementing an analysis of variance on the two samples suggests that the within-territory variation is actually larger than the within-district one.

Second, it could still be asserted that the ecological fallacy results from the too restrictive nature of the territorial boundaries that forbids us to identify the relationship between mining activities and conflict and capture the relationship between any unobserved variable and conflict. The use of territory/district fixed effects overcomes such criticisms. Unobserved factors linked to both conflict and mineral concessions may, however, change over time in a different way at the territory or district levels. That could explain why aggregation at the district level yields different results than at the territory level. That would also lead to the misleading interpretation that has been given to spatially lagged variables (Corrado and Fingleton, 2011). Using socio-economic data from Demographic Health Survey from 2007 (endogenous to conflict), we compare territories (or districts) whose number of conflict events or mineral concessions lies above the sample average, versus the others: conflict-prone areas have higher shares of illiterate people, whilst relatively minerals-rich areas have better access to services (e.g., running water and electricity) and have slightly higher wealth indices. Most important, however, there is no systematic differences between the territory and the district levels, suggesting that the restrictive nature of the territorial boundaries cannot be the feature driving the ecological fallacy (results are reported in the [Supplementary Material](#)).

Third, it is possible that we are capturing at the territory level alternative centrifugal forces to the ‘protection effect’ proposed in the theoretical model. One such possibility would be that mining activities are expanding next to existing mining locations, yet moving across territorial boundaries. This could not explain the negative coefficient obtained for the granting of concessions in the same territory, but it could explain the conflictive impact on neighbouring territories. We address this concern and do not find any evidence of such a centrifugal expansion of concessions: the number of historical concessions is strongly associated with the total number of concessions granted between 1997 and 2007 but not with the total number granted in neighbouring territories (results are reported in the [Supplementary Material](#)).

Fourth, the presence of valuable minerals may translate into a higher opportunity cost for armed group potential recruits, thereby generating a pacifying effect at the local level. This is an appealing theory, well established in the conflict literature. There are a number of reasons we do not believe opportunity cost to be the mechanism driving our results. First, it cannot account for the increase in conflict generated by minerals in neighbouring territories (effect highlighted in [Table 6](#)). Neither is it consistent with the reality of DRC conflicts, where many

of the armed factions were substantially composed by foreigners (Vlassenroot and Raeymaekers, 2004; Prunier, 2009). Finally, even if local recruitment was affected by mining activities, the opportunity cost channel cannot explain the location of the violence: irrespective of the area of recruitment, why would the fighting occur at a certain distance from the mining site?

Next, expanding mining activities may displace farmers by taking over lands previously used for agricultural purposes. Displaced farmers might move into neighbouring territories and join armed groups if alternative economic activities are not available. We cannot exclude a displacement of farmers taking place, following the granting of new mining concessions. If minerals were an important factor in the violence experienced in DRC (as argued here and in a variety of historical accounts), however, this mechanism fails to explain why conflict is located far from the mining sites.

7. Conclusion

We explore the mineral resources—conflict nexus by focussing on the mineral-rich and conflict-ridden DRC from 1997 to 2007. Using geo-referenced data, we investigate whether the DRC government's granting of mineral concessions in particular geographical areas has had an effect on the intensity of conflict. To overcome endogeneity concerns, we instrument concessions granted over the period of analysis by the interaction of historical concessions with the prices of mineral resources. Our study reveals what appears to be a case of ecological fallacy: at the territory level, granting concessions does not affect the level of conflict; at the district level, however, the right to exploit mineral wealth is shown to exacerbate the level of violence.

To rationalize this finding, we set up a theoretical model that relies on the incentives of violent entrepreneurs to protect the mining activities by avoiding armed confrontations with competing armed groups nearby the mining activity. Securing a peaceful environment close to the mining sites enhances the mining labourers' security, thereby reducing the cost of the labour force for the company that controls the mining location. A larger number of mining sites in a particular geographical location is shown to increase the intensity of conflict and provoke a displacement of conflict to more remote locations.

By incorporating the spatial dimension in the econometric analysis, we are able to demonstrate that a displacement of violence is indeed taking place as a consequence of the granting of mining permits, hence providing evidence that is supportive of our theoretical mechanism. Increases in the granting of mining concessions in a neighbouring territory significantly increase the risk of conflict. Moreover, the granting of mining concessions in a particular territory is shown to decrease the level of violence when we account for such spatial effects.

Our article therefore brings forward a crucial element in the understanding of the roots of conflicts, namely, the importance of the geographical unit of observation. Neglecting the spatial dimension may misguide policies. Indeed, we have shown

that natural resources may constitute a blessing for populations located in the neighbourhood of mines since resource-greedy entrepreneurs will deploy means to protect their source of income. The same resources, however, can be characterized as a curse for the wider geographical area since the conflicts in surrounding areas are likely to become more intense.

Supplementary material

[Supplementary material](#) is available online at the OUP website.

Acknowledgements

For helpful suggestions and comments we thank Erwin Bulte, Jean-Francois Carpentier, Olivier Dagnelie, Peter Heudtlass, Macartan Humphreys, Francois Libois, Fergal McCann, Edward Miguel, Jan Fidrmuc, Jo Swinnen, and participants to IFPRI Brown Bag Seminar, the CSAE and the NEPS Conferences, the Wageningen Cooperation and Conflict conference, and the TAMNEAC meeting. We are grateful to Renato Folledo for valuable research assistance.

Funding

European Research Council (AdG-230290-SSD); United States Agency for International Development (SAKSS - DRC).

References

- Angrist, J. and Krueger, A. (2001) Instrumental variables and the search for identification: from supply and demand to natural experiments, *Journal of Economic Perspectives*, 15, 69–85.
- Angrist, J. and Kugler, A.D. (2008) Rural windfalls or new resource curse? Coca, income, and civil conflict in Colombia, *Review of Economics and Statistics*, 90, 191–215.
- Anselin, L. (2002) Under the hood: issues in the specification and interpretation of spatial regression models, *Agricultural Economics*, 27, 247–67.
- Austesserre, S. (2012) Dangerous tales: dominant narratives on the Congo and their unintended consequences, *African Affairs*, 111, 1–21.
- Barr, R. and Pease, K. (1990) Crime placement, displacement and deflection, in M. Tonry and M. Morris (eds) *Crime and Justice: A Review of Research*, vol. 12, University of Chicago Press, Chicago, IL.
- Besley, T. and Persson, T. (2010) State capacity, conflict, and development, *Econometrica*, 78, 1–34.
- Blattman, C. and Miguel, E. (2010) Civil war, *Journal of Economic Literature*, 48, 3–57.
- Brantingham, P.J., Tita, G.E., Short, M.B., and Reid, S.E. (2012) The ecology of gang territorial boundaries, *Criminology*, 50, 851–85.
- Brückner, M. and Ciccone, A. (2010) International commodity prices, growth, and the outbreak of civil war in Sub-Saharan Africa, *Economic Journal*, 120, 519–34.
- Brückner, M., Ciccone, A., and Tesei, A. (2012) Oil price shocks, income, and democracy, *Review of Economics and Statistics*, 94, 389–99.

- Brunnschweiler, C.N. and Bulte, E.H. (2008) Linking natural resources to slow growth and more conflict, *Science*, 320, 616–7.
- Brunnschweiler, C.N. and Bulte, E.H. (2009) Natural resources and violent conflict: resource abundance, dependence, and the onset of civil wars, *Oxford Economic Papers*, 61, 651–74.
- Buhaug, H. and Rod, J.K. (2006) Local determinants of African civil wars, 1970–2001, *Political Geography*, 25, 315–35.
- Collier, P. and Hoeffler, A. (2004) Greed and grievance in civil war, *Oxford Economic Papers*, 56, 563–96.
- Congdon Fors, H. and Olsson, O. (2004) Congo: the size of predation, *Journal of Peace Research*, 41, 321–36.
- Corrado, L. and Fingleton, B. (2011) Where is the economics in spatial econometrics? *Journal of Regional Science*, 52, 210–39.
- Cotet, A. and Tsui, K. (2013) Oil and conflict: what does the cross country evidence really show? *American Economic Journal: Macroeconomics*, 5, 49–80.
- de Koning, R. (2011) Conflict minerals in the democratic republic of the congo: aligning trade and security interventions Stockholm International Peace Research Institute policy paper 27.
- Dube, O. and Vargas, J. (2013) Commodity price shocks and civil conflict: evidence from Colombia, *Review of Economic Studies*, doi:10.1093/restud/rdt009.
- Elhorst, J. (2003) Specification and estimation of spatial panel data models, *International Regional Science Review*, 26, 244–68.
- Elhorst, J. (2010) Spatial panel data models, in M.M. Fischer and A. Getis (eds) *Handbook of Applied Spatial Analysis*, Springer, Berlin.
- Fearon, J.D. (2005) Primary commodity exports and civil war, *Journal of Conflict Resolution*, 49, 483–507.
- Fearon, J.D. and Laitin, D. (2003) Ethnicity, insurgency, and civil war, *American Political Science Review*, 97, 75–90.
- Fessy, T. (2010) Profits from blood gold, BBC News, available from <http://www.bbc.co.uk/news/world-africa-11722142> (accessed 28 May 2013).
- Florax, R. and Folmer, H. (1992) Specification and estimation of spatial linear regression models: Monte Carlo evaluation of pre-test estimators, *Regional Science and Urban Economics*, 22, 405–432.
- Freedman, J. (2011) Tackling the tin wars in Democratic Republic of Congo, *Mineral Economics*, 24, 45–53.
- Gambetta, D. (1993) *The Sicilian Mafia: The Business of Private Protection*, Harvard University Press, Cambridge, MA.
- Gambino, T. (2011) Democratic Republic of Congo, in W. Bank (ed.) *Background Case Study to the World Development Report 2011: Conflict, Security and Development*, World Bank, Washington, DC.
- Haber, S. and Menaldo, V. (2011) Do natural resources fuel authoritarianism? A reappraisal of the resource curse, *American Political Science Review*, 105, 1–26.
- Internal Displacement Monitoring Centre. (2011) Democratic Republic of Congo: IDPs need further assistance in context of continued attacks and insecurity, 14 September, Geneva.

International Alert. (2010) *The Role of Exploitation of Natural Resources in Fuelling and Prolonging Crises in the Eastern DRC*, International Alert, London.

IRC. (2007) *Mortality in the Democratic Republic of Congo: an Ongoing Crisis*, International Rescue Committee, New York.

Johnson, S., Guerette, R.T., and Bowers, K. (2012) Crime displacement and diffusion of benefits, in B. Welsh and D. Farrington (eds) *The Oxford Handbook of Crime Prevention*, Oxford University Press, Oxford.

Le Billon, P. (2001) The political ecology of war: natural resources and armed conflict, *Political Geography*, 20, 561–84.

Lee, L. and Yu, J. (2010) Estimation of spatial autoregressive panel data models with fixed effects, *Journal of Econometrics*, 154, 165–85.

Lujala, P. (2010) The spoils of nature: armed civil conflict and rebel access to natural resources, *Journal of Peace Research*, 47, 15–28.

Lujala, P., Gleditsch, N.-P., and Gilmore, E. (2005) A diamond curse? Civil war and a lootable resource, *Journal of Conflict Resolution*, 49, 538–62.

Maddala, G.S. and Wu, S. (1999) A comparative study of unit root tests with panel data and a new simple test, *Oxford Bulletin of Economics and Statistics*, 61, 631–52.

Mas-Colell, A., Whinston, M.D., and Green, J.R. (1995) *Microeconomic Theory*, Oxford University Press, Oxford.

Mehlum, H., Moene, K.O., and Torvik, R. (2002) Plunder & Protection Inc., *Journal of Peace Research*, 39, 447–59.

Miguel, E., Satyanath, S., and Sergenti, E. (2004) Economic shocks and civil conflict: an instrumental variables approach, *Journal of Political Economy*, 112, 725–53.

Montague, D. (2002) Stolen goods: coltan and conflict in the Democratic Republic of Congo, *SAIS Review*, 22, 103–18.

Pellillo, A. (2012) Conflict and development: evidence from the Democratic Republic of the Congo, Unpublished manuscript, available at https://iweb.cergeei.cz/pdf/events/papers/120402_t.pdf (accessed 28 May 2013).

Prunier, G. (2009) *Africa's World Wars: Congo, the Rwandan Genocide, and the Making of a Continental Catastrophe*, Oxford University Press, Oxford.

Raeymaekers, T. (2010) Protection for sale? War and the transformation of regulation on the Congo-Ugandan border, *Development and Change*, 41, 563–87.

Raleigh, C., Linke, A., Hegre, H., and Karlsen, J. (2010) Introducing ACLED—armed conflict location and event data, *Journal of Peace Research*, 47, 1–10.

Repetto, T. (1976) Crime prevention and the displacement phenomenon, *Crime and Delinquency*, 22, 166–77.

Roskill Information Services. (2002) *The Economics of Tantalum*, 8th edn, Roskill Information Services, London.

Ross, M. (2004) What do we know about natural resources and civil war? *Journal of Peace Research*, 41, 337–56.

Ross, M. (2006) A closer look at oil, diamonds, and civil war, *Annual Review of Political Science*, 9, 265–300.

- Ross, M. (2012) *The Oil Curse: How Petroleum Wealth Shapes the Development of Nations*, Princeton University Press, Princeton, NJ.
- Rudahigwa, P. (2010) *Seventy-Two Hours at the Mining Site of Bisie, in Blood Minerals: The Criminalization of the Mining Industry in Eastern DRC*, Pole Institute—Institut Interculturel dans la Région des Grands Lacs, Goma, DRC.
- Sanchez de la Sierra, R. (2013) Bandits or states? State formation by armed groups in eastern Congo, unpublished manuscript, available at http://cega.berkeley.edu/assets/cega_events/53/WGAPE_Sp2013_Sanchez_de_la_Sierra.pdf (accessed 28 May 2013).
- Spiegel, P.B. and Robinson, C. (2010) Large-scale ‘expert’ mortality surveys in conflicts—concerns and recommendations, *Journal of the American Medical Association*, 304, 567–8.
- Spittaels, S. (2010) *The Complexity of Resource Governance in a Context of State Fragility: An Analysis of the Mining Sector in the Kivu Hinterlands*, International Peace Information Service, Antwerp.
- Stearns, J. (2011) *Dancing in the Glory of Monsters: The Collapse of the Congo and the Great War of Africa*, PublicAffairs, New York.
- Sundberg, R., Lindgren, M., and Padskocimaite, A. (2010) *UCDP Geo-referenced Event Dataset (GED) Codebook*, vers. 1.0, Department of Peace and Conflict Research, Uppsala University.
- The Economist*. (2011) Congo’s outback: Mr Copper, August 18.
- Turner, T. (2007) *The Congo Wars: Conflict, Myth and Reality*, Zed Books, London.
- UN Presidential Statement. (2010) n. S/2010/596, available from <http://www.un.org/> (accessed 3 July 2013).
- van der Ploeg, F. (2011) Natural resources: curse or blessing? *Journal of Economic Literature*, 49, 366–420.
- van der Ploeg, F. and Poelhekke, S. (2010) The pungent smell of ‘red herrings’: subsoil assets, rents, volatility and the resource curse, *Journal of Environmental Economics and Management*, 60, 44–55.
- Verpoorten, M. (2012) Detecting hidden violence: the spatial distribution of excess mortality in Rwanda, *Political Geography*, 31, 44–56.
- Verweijen, J. (2013) Military business and the business of the military in the kivu, *Review of African Political Economy*, 40, 67–82.
- Vlassenroot, K. and Raeymaekers, T. (2004) The politics of rebellion and intervention in ituri: the emergence of a new political complex? *African Affairs*, 103, 385–412.
- Waczarg, R. (2012) The first law of petropolitics, *Economica*, 79, 641–57.
- Wick, A. and Bulte, E. (2006) Contesting resources. Rent seeking, conflict and the natural resource curse, *Public Choice*, 128, 457–76.
- Wong, D. (2009) The modifiable areal unit problem (MAUP), in A. Fotheringham and P. Rogersson (eds) *The Sage Handbook of Spatial Analysis*, Sage, Los Angeles, CA.
- World Bank. (2011) *World Development Report 2011: Conflict, Security and Development*, World Bank, Washington, DC.
- Ziemke, J. (2008) From battles to massacres. mimeo, Yale University, New Haven, CT.